devices (P. Buttolo, B. Hannaford, Pen Based Force Display for Precision Manipulation of Virtual Environments, Proceedings VRAIS-95, pp.217-225, Raleigh, N.C., March 1995.)

[0023] These devices, however, are large, heavy and cannot be easily moved from one workplace to the other. They also usually do not consider interaction design with these devices.

SUMMARY OF THE PRESENT INVENTION

[0024] As described above, the tactile feedback techniques in the related art may not provide the most effective tactile feedback mechanism for a mobile apparatus or a pen-type apparatus that is used with an information processing apparatus for inputting data therein.

[0025] It is, therefore, desirable to provide an apparatus that can present more effective tactile feedback through user interactions. The apparatus may include a haptic device/display, a mobile apparatus, a system including an information processing apparatus and a pen-type apparatus for inputting data therein.

[0026] Furthermore, it is desirable to provide an apparatus that can produce a variety of arbitrary tactile feedback patterns with lesser latency.

[0027] It is also desirable to provide an apparatus that can realize more effective tactile control for a mobile apparatus In view of the above problems, there is provided a mobile apparatus having tactile feedback function comprising:

[0028] a data processing unit for executing data processing operation;

[0029] a signal producing unit for producing the signal that is a voltage function of time, with amplitude, shape and period defined by the resultant data from the data processing unit; and

[0030] a haptic display for generating immediate tactile pattern, to be communicated to the user who touches the mobile apparatus, in accordance with the signal applied by the signal producing unit.

[0031] With the mobile apparatus according to the first aspect of the invention, it is possible to give user effective tactile feedback through the user interaction.

[0032] The force patterns can be freely changed by applying arbitrary control signal to the haptic display. The signal producing unit generates, in accordance with the resultant data from the data processing unit, the control signal that is a voltage function of the time.

[0033] The mobile apparatus according to the present invention may further comprise a user input device for receiving data or command inputted by the user. In this case, the data processing unit handles the inputted data or command, and the signal producing unit generates the signal influenced by the inputted data or command. Resultantly, the haptic display can give the tactile feedback in accordance with the user-input-operation.

[0034] The haptic display may be constituted by a bending actuator. More specifically, it may comprise a multi-layered piezoelectric bending actuator, that has an upper layers of piezoelectric actuators and a lower layers of piezoelectric actuators.

[0035] The piezoelectric material can either expand or contract in accordance with the direction of the applied voltage. By applying voltage of the opposite direction to the upper and lower layers, the upper layer contracts and the lower layer expands at the same time. Resultantly, the multiple layer piezoelectric bending actuator bends upward or downward as a whole.

[0036] Alternatively, the haptic display may include one or more bending-type actuators. The bending-type actuator may include a beam portion preferably with a plate-like form, and bend in response to the signal outputted from the signal producing unit.

[0037] Preferably, the bending-type actuator may be a multi-layered piezoelectric bending actuator that has layers of piezoelectric material and electrodes. Each of the layers of piezoelectric material is sandwiched by a pair of electrodes.

[0038] Examples of the multi-layered piezo electric bending actuator are disclosed in, for example, non-published Japanese Patent Application JP 2002-25178, filed on Aug. 29, 2002 and assigned to same applicant of this application. The entire disclosure of the art is incorporated herein.

[0039] Furthermore, the multi-layered piezoelectric bending actuator may include a first bending actuator unit, second bending actuator unit and a common electrode layer sandwiched between the first and second bending actuator units. Each of the bending actuator units has a multi-layered configuration with a plurality of piezoelectric layers and electrodes. The first and second bending actuator units may be driven in such a way that an overall construction of the first bending actuator unit contract when the second bending actuator unit expand or vise versa.

[0040] The piezoelectric material may be piezoelectric ceramics such as PZT or any other material that exhibits the piezoelectric property, i.e. converts electric energy to mechanical energy.

[0041] It would be appreciated that the value ΔY of the multiple layer piezoelectric bending actuator is much larger than the longitudinal contraction and expansion of the each layer. The multiple layer piezoelectric bending actuator consumes lower power, and can activate with very small latency. And, most important, this actuator requires significantly lower voltage for its operation (5-10V) which allows to control it from the battery. The traditional 2-layers actuators (bimorphs) require at least 40V voltage which makes them inappropriate for small battery-powered devices.

[0042] By using the multiple layer piezoelectric bending actuator, it is possible to form the haptic display into small and thin chip.

[0043] The haptic display may be located anywhere in the mobile apparatus. In response to the user-input-operation or in accordance with the data processing result, the body of the mobile apparatus gives the user the immediate tactile feedback having a wave of any shape.

[0044] The haptic display may be attached to a movable part or deformable part of the mobile apparatus. If such part is suspended on the apparatus body, only this part among the apparatus body can provide tactile feedback.

[0045] The haptic display may also attached so as to actuate a movable part of the mobile apparatus. For example, it can be embedded under the touch panel display.